EFFECT OF SEASON OF SEEDING AND MULCHING TREATMENT ON REVEGETATION SUCCESS ON IN SITU OIL SHALE RETORTS

STUDY PLAN

By

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Geokinetics, Incorporated of Salt Lake City, Utah is presently extracting oil from oil shale located in the southern portion of Utah's Uinta Basin by an in situ retorting process. The method used involves fragmenting the oil shale by setting off precisely placed explosive charges. Following fragmentation, holes are drilled into the shale layer and the shale is ignited. Air is forced into the holes to supply oxygen to sustain combustion. As the combustion front progresses horizontally, the kerogen in the shale is pyrolized and condensed. The synthetic crude then drains to the retort bottom and is recovered through pump wells.

The first of these in situ retorts were small (400 sq. ft. to less than 1/3-acre). However, recently developed retorts have approached two acres in size. The oil shale rock has been covered by only 2 to 60 feet of overburden. As a result of the fragmentation of the shale by explosives, the overlying material is lifted up to form a mound over the fractured zone of shale. Such mounds may be as much as 8 feet (usually less) higher than the original land surface.

The land surface immediately above the retort is usually denuded of vegetation in the process of drilling and pumping. It is often necessary to remove pinyon or juniper trees to facilitate the procedure. The area adjacent to the retorts is also disturbed by the movement of equipment and vehicles.

Efforts have been made since about 1979 to develop successful methods of re-establishing a vegetative cover on retort areas from which the extraction of shale oil has been completed. These efforts have met with limited success, especially on the "raised" portion of the retorts where soil material is often shallow. Some areas around the edges of the raised retorts have supported good stands of grass. Thus the primary obstacle to successful establishment of adequate vegetation appears to be a lack of soil depth. Associated with

the factor of soil depth is the necessity to prepare the soil surface in a manner that will retain precipitation or applied supplemental water on the area and hold surface runoff to a minimum.

There is a need to include adapted legume and shrub species in revegetation planning. Several adaptability trials made on smaller retort areas of the Geokinetics site have revealed a number of shrubby and herbaceous species that can be used in reclamation. However, most of the species tested to date have been plants that are not native to this part of Utah, or were native species the seed of which was collected in other parts of Utah or the Intermountain West. Local sources of native shrub species should be tested to determine their competitive capacity when used in a seed mixture.

This study is designed to yield information on alternative cultural methods and suitable herbaceous and shrubby species for establishing a level of vegetative cover adequate to meet government reclamation requirements. Specific objectives are: (1) to determine the relative success of direct seeding in conjunction with three mulching treatments (straw, wood fiber, or no mulch), (2) to evaluate the vegetative stand obtained when only herbaceous species are used or when both herbaceous and shrubby species are used. (3) to obtain preliminary information on the value of supplemental water, applied by irrigation during the growing season, on successful vegetation establishment, (4) to assess the effect of season of direct seeding (spring vs. autumn) on vegetation establishment, and (5) to determine the success of establishment of several native shrub species when direct seeded in association with perennial grasses.

STUDY AREA

Location of the study area is on lands owned by the State of Utah, and leased by Geokinetics, Incorporated, in Section 2, Township 14 South, Range 22 East, Uintah County.

Elevation at the site is approximately 6,700 feet (2 042 m). Average Annual precipitation is about 13 inches. Native vegetation of the area is dominated by the pinyon-juniper type, with locally interspersed areas of sagebrush-grass and sagebrush-saltbush types. Soils are well drained, and derived primarily from ~~shale and sandstone~~ marlstone parent material.

METHODS

A 1.25- acre retort (Geokinetics No. 24) was selected by Geokinetics for use in this study.

Shale oil extraction from the retort began in December, 1980 and was completed in July, 1981. The top of the burned oil shale layer was approximately 45 feet below the original ground surface. Retorting was begun under the southeast end of the retort and proceeded toward the northwest end.

Upon completion of shale oil extraction, the retort surface was covered with approximately four inches of the topsoil material that was originally removed in preparation for "burning" the retort, and then reshaped to minimize the slopes around the retort perimeter (Appendix Figure 1).

Soil samples were taken from the top 12 inches of the soil material in November, 1982, and exhibited the following characteristics:

Soil reaction (pH): 8.0-8.4 ($\bar{x}$ = 8.1)

electrical conductivity (ECe): 2.6-6.8 ($\bar{x}$ = 4.6)

phosphorous (ppm): 1.6-7.8 ($\bar{x}$ = 3.7)

potassium (ppm): 284-400 ($\bar{x}$ = 348)

sodium (meq /l); 8.3-42.2 ($\bar{x}$ = 24.6)

estimated SAR: 2.8-14 ($\bar{x}$ = 7.4)

Treatments

The following five treatments will be applied on the retort area; half of the area will be treated in early April 1983, and the remaining half will be treated in October or November, 1983. (The plot design is shown in Appendix Figure 1):

(A) seeded with a grass-forb mixture, and muched with straw

(B) seeded with a grass-forb mixture, and mulched with wood fiber

(C) seeded with a grass-forb-shrub mixture and mulched with straw

(D) seeded with a grass-forb-shrub mixture, and mulched with wood fiber.

(E) seeded with a grass-forb-shrub mixture, but not mulched

The seed mixture will be as follows, contingent on availability of seed:

For treatments A and B:	lbs./acre PLS
Bouteloua gracilis; "Lovington"	1
Sporobolus airoides	0.5
Oryzopsis hymenoides; "Nezpar"	3
Agropyron elongatum; "Alkar"	6
Agropyron inerme; "Whitmar"	4
Agropyron smithii; "Rosanna"	4
Ag. spicatum X Ag. repens; ARS hybrid	3
Elymus junceus	4
Hedysarum boreale	2
	27.5

For treatments C, D, and E:	lbs./acre PLS
Bouteloua gracilis; "Lovington"	1
Sporobolus airoides	0.5
Oryzopsis hymenoides; "Nezpar"	2
Agropyron elongatum; "Alkar"	3
Agropyron inerme; "Whitmar"	2
Agropyron smithii; "Rosanna"	2
Ag. spicatum X Ag. repens; ARS hybrid	1.5
Elymus junceus	2
Atriplex canescens	5.7
Atriplex confertifolia	4.9
Artemisia tridentata	0.4
Ceratoides lanata	3.2
Chrysothamnus nauseosus	0.13
Hedysarum boreale	2
	30.33

Site Preparation, Seeding, and Mulching

Prior to seeding, inorganic fertilizer will be broadcast on the entire study area at the rate of 60 lbs/acre of nitrogen and 51 lbs/acre of phosphorus. Fertilizer will be incorporated into the top 12 to 14 inches of soil by ripping and harrowing. In addition, gypsum will be applied, with the fertilizer, at a rate of 1 ton per acre.

Seed will be sown with a Brillion seeder-cultipacker, drawn by a small caterpillar tractor. Sufficient seed will be placed in the seed hopper to permit the seeding of treatments A and B first (no shrub seed included). Once treatments A and B are completed, the seed hopper will be loaded with

sufficient grass and forb seed to seed treatments C, D, and E. However, shrub seed will be mixed together and divided into small packets, with one packet of seed added to the seed hopper as each 5-ft by 175-ft strip is sown.

Mulching material will be applied immediately after seeding. Straw will be spread at 2,400 lbs/acre and tacked down with a straw crimper. Wood fiber will be blown on at a rate of one ton per acre.

Provision for Supplemental Water

One-half of both the spring and autumn seeded areas will be sprinkler irrigated. Irrigation will begin no later than April 15, and will be applied at a rate of 1 inch of water on the initial date of irrigation and 0.5-inches of water at weekly intervals thereafter, through September 2. This is equivelent to 11 inches of water (298,700 gallons/acre) for the 21-week period.

Soil water potential will be monitored twice monthly, beginning 6 days after the date of initial irrigation, through the use of thermocouple psychrometers. Preferrably, readings will be made on the day prior to each irrigation, or immediately before turning on the irrigation system. Psychrometers will be placed in the soil at four locations on the irrigated half of the seeded area and at four locations on the non-irrigated area. At two of the four locations, psychrometers will be placed at depths of 4, 8, and 12 inches, while at the other two locations an additional psychrometer will be placed at a depth of 24 inches. Soil temperature can be monitored with the same thermocouple psychrometers.

Experimental Design

The study will be set up as a stratified randomized, split plot design, with five blocks. Each treatment will be represented in each block by a 10-ft-wide by 100-ft-long strip (Appendix Figure 2).

Data will be taken on percent frequency in August of each growing season, using a nested plot plot method, as described in section 4.63 of FSH 2209.21 R-4 (Range Analysis Handbook). In each 10-ft by 50-ft strip (representing a single treatment in each "block"), a 10-sq-ft sampling frame will be placed down five times. The locations will be chosen by drawing random numbers from 0 to 49, which in turn represent 1-foot segments along a tape stretched along one side of the strip to be sampled. If the number is even, the frame will be placed down on the left half of the 10-ft-wide strip; if the number is odd, the frame will be placed down on the right half of the strip. The 10-sq-ft frame is divided into 10-sq ft subplots, one of which is further divided into 9-sq-dm subplots. Each time the frame is placed down, the presence of each specific class or species being sampled will be recorded in four sizes of plot, i.e. 10 sq ft, 5 sq ft, 1 sq ft, and 1 sq dm. Percent aerial cover of vegetation will also be sampled by estimating the percent cover in the four 1-sq-ft corner segments of the frames each time it is laid down.

In August 1983 "grasses" will not be sampled by individual species because of the tediousness of distinguishing species of very young plants. Similarly, in August 1984 grasses from the seeding made in the autumn of 1983 will be tallied as a class. Forbs and shrubs will be recorded by individual species on each sampling date. Grass species should be recognizable by the second growing season.

Beginning with the 1985 sampling, data will be taken on yield, by species, utilizing the same randomly located 10-sq-ft plots from which frequency data are obtained. It may be desirable to sample in July instead of August, beginning in 1985. The weight-estimate method will be used for sampling yields.

Data on percent frequency and yield will be subjected to analysis of variance, as outlined below.

	d.f.
Blocks (5)	4
Treatments (5)	4
Error	16
	24

If analyses of variance tests indicate significant differences between treatments, data will be examined and a decision made on appropriate transformation and multiple comparison methods.

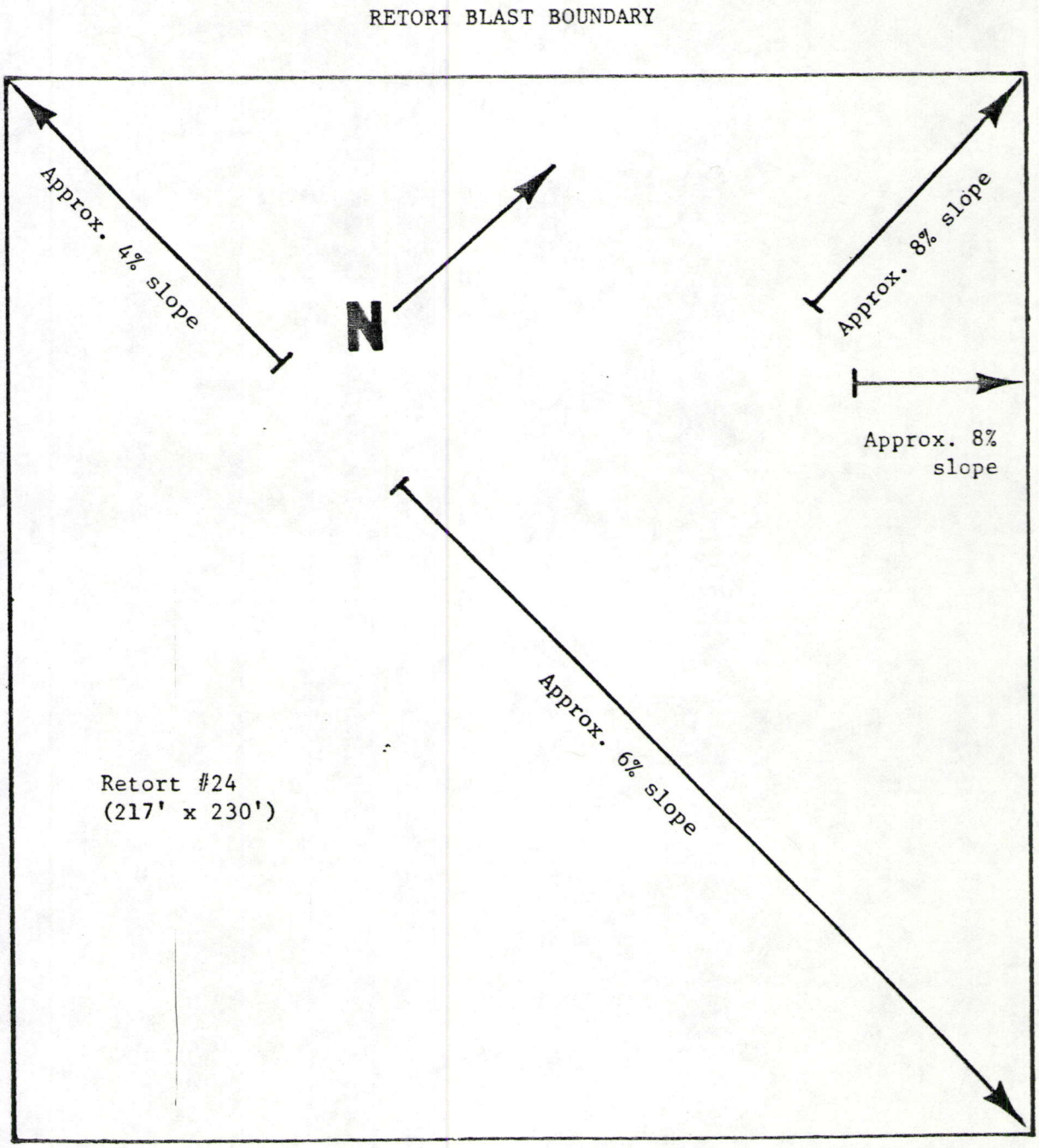
Study Establishment and Data Collection

Personnel of the Intermountain Forest and Range Experiment Station will prepare the retort surface and make the seedings, both in the spring and autumn of 1983. Station personnel will also install the irrigation system, with the assistance of Geokinetics personnel, sud will install thermocouple psychrometers as outlined in the study plan.

Data on vegetation parameters will be obtained by Intermountain Station personnel. Data on soil water potential will normally be collected by Geokinetics personnel, as it would be too expensive for Station personnel to travel to the study site from Logan or Provo on a weekly or bi-weekly basis.

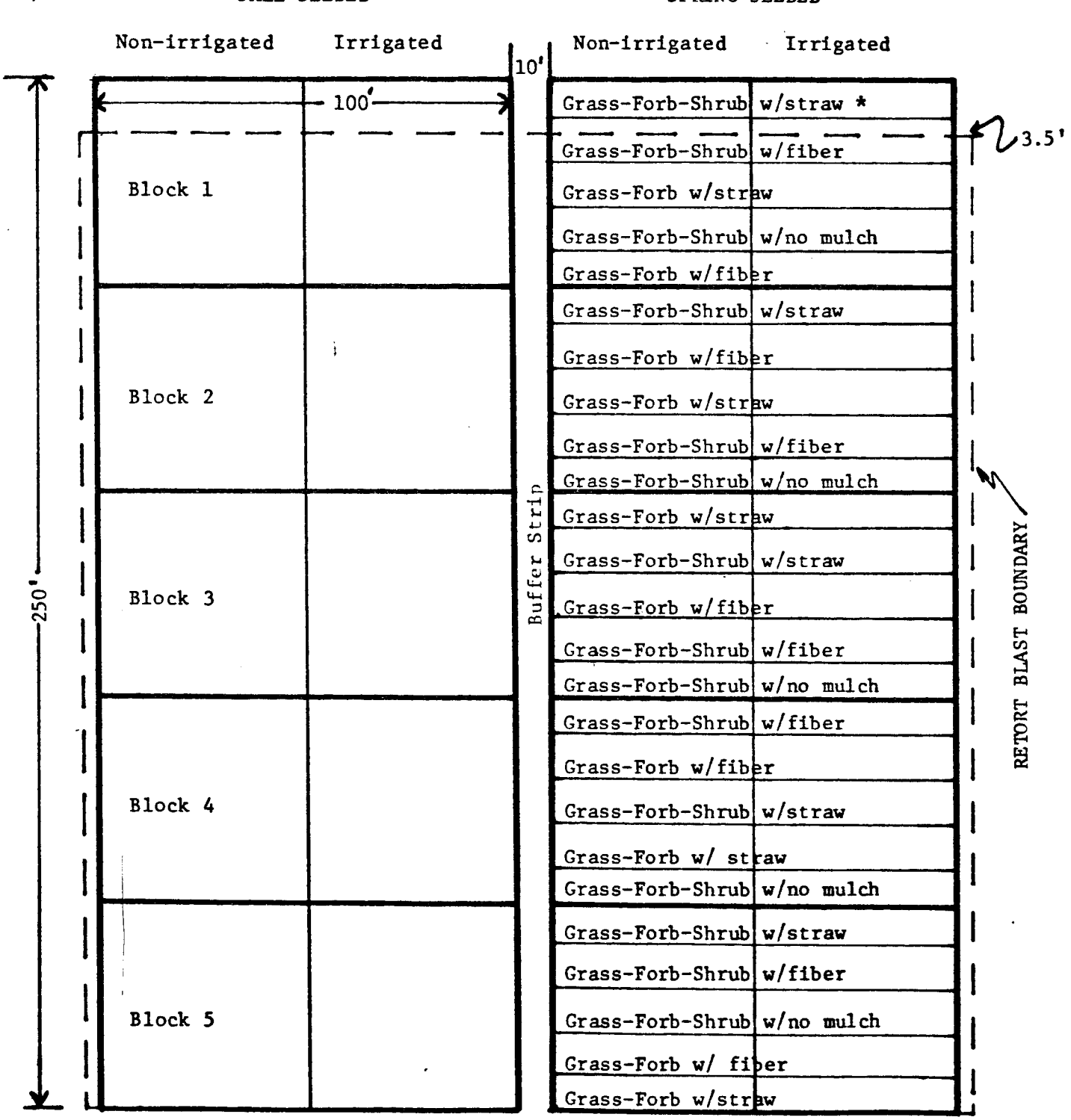
Geokinetics, Inc. will apply supplemental water as scheduled, or deemed to be needed, depending on natural precipitation received.

Appendix Figure 1. Approximate configuration of Geokinetics Retort No. 24 following surface shaping.



Scale: 1 in. = 35 ft.

Appendix Figure 2. Field plot design for Retort No. 24, showing season of seeding, treatment sequence within each block, and irrigated vs. non-irrigated portions.



* Order of treatments is the same in both spring and fall seedings.

Bill

SPRING

EFFECT OF SEASON OF SEEDING AND MULCHING TREATMENT

ON REVEGETATION SUCCESS ON IN SITU OIL SHALE RETORTS

ESTABLISHMENT REPORT

The spring seeding phase of the study was done May 23 and 24, 1983. Cold, wet weather prevented working the soil until May 1, and the work schedule of Intermountain Station personnel prevented our doing the seeding during the first week of May. An effort was made to accomplish the job the week of May 9; but, once again, snow storms made the soil too wet.

The application of gypsum and inorganic fertilizer was made as described in the study plan. Both materials were spread on the test area (prior to ripping and harrowing) through the use of a two-wheeled fertilizer spreader pulled by a small, wheeled tractor.

The shrub seed was broadcast by hand, to ensure an even distribution. The grass and forb seed was mixed together and sown with the Brillion seeder-packer, after the shrub seed had been sown. Thus, the Brillion also served to press the shrub seed into the soil. In addition to the species shown in the study plan, the following forbs were added to the mixture for all treatments: Sphaeralcea munroana, Sphaeralcea grossulariaefolia, and Penstemon palmeri.

At the completion of seeding on treatments A and B there was 1.2 pounds of the grass-forb seed mixture remaining in the seed hopper. Thus, the actual seeding rate for these treatments was:

	lbs/acre, PLS
Blue grama	1.1
Alkali sacaton	0.6
Indian ricegrass	3.3
Tall wheatgrass	6.7
Beardless wheatgrass	4.4
Western wheatgrass	4.4
Bluebunch wheatgrass-Quackgrass hybrid	3.3
Russian wildrye	4.4
Utah sweetvetch	1.4
Munro globemallow	0.06
Gooseberry-leaf globemallow	0.29
Palmer penstemon	0.24
TOTAL	30.09

Mulching material (straw or wood fiber) was applied to the seeded area as prescribed. Some difficulty was encountered in limiting the blown straw to only the treatments for which it was intended. However, part of the straw that fell on areas of the other treatments was raked off, and it is expected that the relatively small amount remaining will have little effect on those areas.

At the completion of seeding of treatments C, D, and E there was 2.17 pounds of the grass-forb seed mixture remaining in the seed hopper of the Brillion seeder. Thus, the actual seeding rate for treatments C, D, and E was:

	lbs/acre, PLS
Blue grama	.58
Alkali sacaton	.29
Indian ricegrass	1.16
Tall wheatgrass	1.74
Beardless wheatgrass	1.16
Western wheatgrass	1.16
Bluebunch wheatgrass-Quackgrass hybrid	1.74
Russian wildrye	1.16
Utah sweetvetch	.74
Munro globemallow	.03
Gooseberry-leaf globemallow	.15
Palmer penstemon	.12
Fourwing saltbush	5.70
Shadscale	4.90
Big sagebrush	.40
Winterfat	3.20
Rubber rabbitbrush	.13
TOTAL	24.36

Thermocouple psychrometers were buried at two locations on the portion of the site that will be irrigated, and on two locations on the portion that will not be irrigated. Psychrometer numbers and their locations are shown below:

PSYCHROMETERS LOCATED AT GEOKINETICS STUDY SITE ON MAY 25, 1983

Treatment E (irrigated), Block No. 2:

Psychrometer No.	Depth (in.)
12	4
1	8
11	12

Treatment C (irrigated), Block No. 4:

Psychrometer No.	Depth (in.)
16	4
8	8
14	12
20	24

Treatment C (non-irrigated), Block No. 4:

Psychrometer No,	Depth (in.)
22	4
24	8
27	12

Treatment E (non-irrigated), Block No. 2:

Psychrometer No.	Depth (in.)
7	4
19	8
4	12
10	24

The sprinkler irrigation system was installed by Geokinetics personnel May 25 and 26 with irrigation scheduled to begin immediately.

FALL

EFFECT OF SEASON OF SEEDING AND MULCHING TREATMENT ON REVEGETATION SUCCESS ON IN SITU OIL SHALE RETORTS

ESTABLISHMENT REPORT

The autumn seeding phase of the study was done October 25 and 26, 1983. Weather during the two days of work was cool and sunny, with virtually no wind.

Gypsum and inorganic fertilizer was applied in the same manner as for the spring seeding. The study area was then "ripped" across the short dimension of the site with a road grader, followed by ripping across the long dimension of the site with the small caterpillar. The site was next harrowed with a springtooth harrow prior to seeding.

As in the spring, the shrub seed was broadcast by hand, to ensure an even distribution, prior to sowing of the grass and forb seed with the Brillion seeder-packer.

The seeding rate was intended to be the same as that used in the spring seeding. This was accomplished reasonably well on the grass-forb seeded areas, with 1,025 grams remaining the seed hopper after all 10 strips had been seeded. However, when only 30 percent of the seeding operation on the grass-forb-shrub strips had been completed it was realized that seed was being dispensed from the Brillion seeder in greater than the desired quantity. The setting on the hopper of the Brillion was then changed from the "wide open" position to a setting of "3" for the seeding of the remaining 70 percent of the area. Thus, as closely as can be determined, the seeding rate for the autumn seeding was as follows:

For treatments A and B--

	lbs/acre, PLS
Blue grama	1.0
Alkali sacaton	.5
Indian ricegrass	2.9
Tall wheatgrass	5.9
Beardless wheatgrass	3.9
Western wheatgrass	3.9
Bluebunch wheatgrass-Quackgrass hybrid	3.0
Russian wildrye	3.9
Utah sweetvetch	1.3
Munro globemallow	.06
Gooseberry-leaf globemallow	.26
Palmer penstemon	.21
TOTAL	26.8

For treatments C, D, and E--

	lbs/acre, PLS	
Blue grama	0.9	(1.9)[1]
Alkali sacaton	0.5	(1.0)
Indian ricegrass	1.9	(3.9)
Tall wheatgrass	2.9	(5.8)
Beardless wheatgrass	1.9	(3.9)
Western wheatgrass	1.9	(3.9)
Bluebunch wheatgrass-Quackgrass hybrid	2.9	(5.8)
Russian wildrye	1.9	(3.9)
Utah sweetvetch	0.7	(1.1)
Munro globemallow	.06	(0.1)
Gooseberry-leaf globemallow	.25	(0.5)
Palmer penstemon	.20	(0.4)
Fourwing saltbush	5.7	
Shadscale	4.9	
Big sagebrush	.4	
Winterfat	3.2	
Rubber rabbitbrush	.13	
TOTAL	30.34	(46.5)

[1]Amount in parentheses is the estimated seeding rate for treatments C, D, and E in Block 5, and treatment E and the south 1/2 of treatment C in Block No. 4 of the autumn-seeded area.

For the record, we had started seeding of the grass-forb-shrub treatments in Block No.5, and had progressed through the south one-half of treatment C

in Block No. 4 when we realized that seed was being spread in too great a quantity. Thus, it should be recognized, in future evaluations of the established vegetation, that these portions of the autumn-seeded area were seeded quite heavily!

Thermocouple psychrometers were installed at two locations on the portion of the autumn-seeded area that will be irrigated, and at two locations on the portion that will not be irrigated. Psychrometer numbers and their locations are shown below:

PSYCHROMETERS LOCATED AT GEOKINETICS

STUDY SITE ON OCTOBER 26, 1983

Treatment B (irrigated), Block No. 2

Psychrometer number	Depth (in.)
26	4
28	8
21	12

Treatment C (irrigated), Block No. 4

Psychrometer number	Depth (in.)
2	4
5	8
18	12
13	24

Treatment B (non-irrigated), Block No. 2

Psychrometer number	Depth (in.)
6	4
9	8
25	12
3	24

Treatment C (non-irrigated), Block No. 4

Psychrometer number	Depth (in.)
15	4
23	8
162	12

Revegetation of 10 acres of disturbed land was completed between October 26th and November 4th, 1983 for the purpose of:

1. Return the land concurrently with process operations, or within a reasonable amount of time thereafter to a stable ecological condition compatible with past, present and probable future local land use;

2. Minimize or prevent present and future on-site or off site environmental degradation caused by Geokinetics operations to the ecologic and hydrologic regimes, and

3. Minimize or prevent future hazards to public safety and welfare.

The revegetated land consist of two areas: (1) Retorts #3 through #26 (excluding 7, 11, 13, 16, 19, 20, 22 and 24) with adjacent areas; and (2) Retorts #21 and #23 with additional non-retorted area (Appendix D).

The pre-disturbed native vegetation of the areas was dominated by sagebrush-grass and sagebrush types with interspersed areas of the pinyon-juniper type. Soils are silt loam derived primarily from a marlstone parent material.

Approximately 1.5 ac.-ft. of topsoil was stripped from the Retort #SR7 area (Appendix D) and redistributed over Retorts #25 and #26. Soil Samples were taken from the top 12 inches of the soil profile in the disturbed ares during September and exhibited the follwoing characteristics:

Soil reaction (pH): 8.3 - 9.1 ($\bar{x}$ = 8.8)

Electrical conductivity (mmhos/cm): 0.6 - 5.7 ($\bar{x}$ = 1.8)

Organic matter (%): 1.7 - 4.2 ($\bar{x}$ = 2.5)

Available nitrogen (ppm):" 0.4 - 7.1 ($\bar{x}$ - 4.0)

Available phosphorous (ppm): 0.01 - 0.58 ($\bar{x}$ = 0.12)

Sodium (meq/1) 8.3 - 42.2 ($\bar{x}$ = 24.6)

Estimated SAR: 2.8 - 8.6 ($\bar{x}$ = 5.3)

Two separate native-introduced seed mixtures, Mix A and Mix B, were used on the disturbed areas. Mixture A, used on Area 1, was primarily collected locally (within the Uintah Basin), and Mixture B, used on Area 2, was primarily collected outside of the local area. The purpose of the two different mixtures is to, in general terms, distinguish whether a local seed collection will have greater establishment and long-term success over a mixture collected outside of the local area. Individual plant species of the two mixtures are listed as follows:

Common Name	Scientific Name	Seeding Rate PLS (lbs/ac)
Mixture A - Locally Collected		
1. Western wheatgrass	Agropyron smithii	3.4
2. Intermediate wheatgrass	A. intermedium	3.2
3. Blue gramma	Bouteloua graeilis	1.4
4. Indian Ricegrass	Oryxopsis hymenoides	1.2
5. Bottlebrush squirreltail	Sitanion hystrix	1.1
6. Russion wildrye	Elymus junceus	1.3
7. Green mormon tea	Ephedra viridis	0.9
8. Antelope bitterbrush	Purshia tridentata	1.3
9. Winterfat	Ceratiodes lanata	1.9
10. Four-wing saltbush	Atriplex canescens	2.9
11. Northern sweetvetch	Hedysarum boreale	1.1
12. Rocky Mountain penstemon	Penstemon strictus	0.2
13. Scarlet globemallow	Sphaeralcea coccinea	0.3
		20.2
Mixture B - Non-local Collection		
1. Western wheatgrass	Agrpoyron smithii	2.9
2. Tall wheatgrass	A. elongatum	2.1
3. Bearded bluebunch wheatgrass	A. spicatum inerme	3.6
4. Russian wildrye	Elymus junceus	1.6
5. Blue gramma	Bouteloua gracilis	1.2
6. Alkali sacaton	Sporabulus airoides	1.0
7. Indian riecgrass	Oryxopsis hymenoides	3.1
8. Nevada mormon tea	Ephedra nevadensis	0.8
9. Antelope bitterbrush	Purshia tridentata	0.8
10. Fourwing saltbush	Atriplex canescens	1.2
11. Shadscale	A. confertifolia	0.5
12. Winterfat	Ceratoides lanata	0.8
		19.6

Prior to seeding, inorganic fertilizer was broadcast on both areas at a rate of approximately 65 lbs/acre of nitrogen in the form of ammonium sulfate, and 45 lbs/acre of phosphorus in the form of triple superphosphate. The fertilizer was incorporated into the top foot of soil by shallow ripping and chisel plowing.

Both seed mixtures were sown with a Brillion seeder - cultipacker, drawn by a dual-wheeled conventional farm tractor.

The revegetated areas will be visually inspected in the spring of 1984 to determine the degree of seed germination, as well as, quantitatively sampled in the early fall of 1984 for first-year success.

In addition, the topsoil stockpile was seeded twice during 1983: first during June 1983 with a annual cover (annual ryegrass); and secondly during November 1983 with a more permanent plant cover.

The November seed mixture was as follows:

Common Name	Scientific Name	Seeding Rate
Tall Wheatgrass	Agropyron elongatum	6.0
Russion Wildrye	Elymus junceus	6.0
Prostrate Kochia	Kochia prostrata	0.3
Annual Ryegrass	Lolium mutiflorum	6.0
		18.3

The seed mixture was drilled into the annual ryegrass stubble with a standard grain drill.